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FIRST REPORT OF FUNGAL INFECTED WOOD OF *TERMINALIA TOMENTOSA* FROM HOLOCENE SEDIMENTS OF TANAKPUR AREA, INDIA: ITS PHYTOGEOGRAPHIC AND PALAEOCLIMATIC IMPLICATION

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ABSTRACT

Fossil wood collected *in-situ* from the Holocene (1100 AD ± 80 year) sediments exposed all along the Sharda River near Thuligad in the Tanakpur area, Uttarakhand has been investigated. The wood is characterised by medium to large usually solitary and evenly distributed vessels having simple perforation plate with elliptic aperture, paratracheal and apotracheal parenchyma, exclusively uniseriate heterocellular xylem rays with frequent crystalliferous cells. The present finding is phytogeographically important as provide the evidence of its entry in the Himalayan foot hills before 913 yrs. and flourished there luxuriantly since then. The comparable taxa, *Terminalia tomentosa* W. & A. is a large tropical moist deciduous tree found commonly in the forest, especially in the humid regions of Himalayan foot hills suggesting the prevalence of tropical humid climate. The presence of fungal spores in the vessels of present fossil wood also suggested the same view regarding the climatic conditions.

KEYWORDS: Fossil Wood, Terminalia (Combretaceae), Holocene, Phytogeography, Deciduous, Climate

1. INTRODUCTION

The Holocene sediments deposited in between the hillocks of foot hills by the erosion of Siwalik sediments exposed around it are composed of hard yellowish grey clay with some conglomerates having small to large pieces of fossil wood. Several studies on the origin and history of tropical forest in different regions of Uttarakhand has been carried out based on both mega and microfossils to deduce the different stages involved in the formation of present Sal dominating forest during Holocene (Chauhan *et al*,2002).

So far, two fossil woods have been recorded from the Holocene sediments of Tanakpur area showing affinity with *Shorea robusta* Roxb. of the family Dipterocarpaceae (Prasad and Khare, 2008a) and *Anogeissus latifolia* Wall. of family Combretaceae (Prasad and Khare, 2008b). Besides, few fossil leaves showing affinity with extant genera, *Celtis, Mallotus, Prunus* and *Ficus* have also been recorded from the Holocene sediments of India (Tiwari *et al*. 2002; Mahajan & Mahabale, 1973; Prasad *et al*., 2002). A large number of fossil leaves showing the affinity with moist deciduous and evergreen taxa have also been recorded from Miocene (12Ma.) sediment of this area (Lakhanpal & Guleria,1978, Shashi *et al*. 2006, Prasad *et al* 2013). With a view to generate megafossil data to reconstruct Holocene floristics, the present study has been made on the fossil woods collected from Holocene sediments of Sharada river section near Purniyagiri temple, Tanakpur. The anatomical study of the fossil woods revealed the occurrence of *Terminalia tomentosa* W. & A. which has been described and discussed in present communication. Although the genus being described herein are already known

from various Palaeogene and Neogene sediments of India and abroad (Prakash,1966; Prasad,1989; Tiwari & Mehrotra, 2000; Table), this is its first record from Holocene sediments.

2. MATERIALS AND METHODS

Fossil wood piece was taken out from a large wood log embedded in the Holocene sediments of Sharda river section (29° 04' 39" N and 80° 09'40" E) near Purniyagiri temple in the Chapawat district of Uttarakhand. (Figure 1) This wood piece was boiled in glycerine water before sectioning it. It was sectioned in three planes (TS, TLS, and RLS) with the help of Microtome and permanent slide were prepared by using Canada balsam. The comparative anatomical study of fossil wood slides as well as the slide of modern woods was done under high power microscope. The anatomical terms used in describing them are those adopted by Wheeler *et al.* (1986) and International Association of Wood Anatomist (1989). The specimen and figured slides have been deposited in the Repository of Birbal Sahni Institute of Palaeobotany, Lucknow. The photographs were taken with the help of Digital camera (DS-20) attached to the microscope.

The carbon C_{14} dating was carried out on wood sample using Walla 1220 Quantulum Ultra low level Liquid Scintillation Counter as per standard procedure (Rajagopalan *et. al.* 1978, Gupta & Polach, 1985) at Radio Carbon dating Lab. of BSIP, Lucknow. The age was calibrated using CALIB, Version 4.3 and found as 1100±80 yrs.

3. SYSTEMATIC DESCRIPTION OF FOSSIL WOOD

Family- Combretaceae

Genus- *Terminalia* Linn.

Terminalia tomentosa W.& A.

Figures 3 (A-K)

3.1 Fossil Wood

The fossil wood log is measuring about 13 cm. in length 4 cm. in width.

Description*:* *wood* diffuse porous, *Growth ring* distinct. : *Vessels* medium to large sized, t.d. 120-240 µm, r.d. 125-310 µm, usually solitary to radial multiples of 2-4, 6-12 per sq.mm, *tyloses* present, moderately thick walled, round to oval in shape, vessel segments 140-680 µm long with truncate to tailed end, perforation simple inter-vessel pits circular to oval, 4-6 µm in diameter with usually elliptic apertures. *Parenchyma* both apotracheal and paratracheal, apotracheal parenchyma abundant, confluent to banded, parenchyma band 2-6 cells wide, paratracheal parenchyma scanty to aliform, parenchyma cells thin walled,12-20 µm in diameter and 136-476 µm in length. *Xylem rays* fine, exclusively uniseriate, 14- 16 rays per mm, 2-28 cells or 18-900 µm in length, cells 16-40 µm in diameter. Ray tissues heterogeneous crystalliferous, oval to barrel shaped, 1-2 upright cells at one or both ends, ray cells thin walled procumbent, cells 40-45 µm in vertical height and 35-95 µm in radial length, upright cells 20 µm in radial length and 36-70 µm in vertical height. Fibers arranged in radial rows between two consecutive xylem rays, semi libriform, polygonal in cross section, septate, about 12 µm in diameter 90-425 µm in length. Fungal spore circular to oval in shape, thin walled, 65 to 100 µm in diameter.

Modern Affinity

The characteristic features of the fossil wood such as medium to large usually solitary rarely in radial multiple of 2-4 and evenly distributed vessels with simple perforation plate with elliptic aperture, paratracheal and apotracheal parenchyma, exclusively uniseriate, heterocellular xylem rays with frequent crystalliferous cells and septate fibres indicate its affinity with the modern woods of *Terminalia* Linn. of the family Combretaceae. In order to find out specific affinity of the fossil wood, thin section of modern woods of extant genus, *Terminalia* Linn. have been examined. Besides, the literatures pertaining to anatomy of other species of this genus were also consulted (Pearson & Brown, 1932; Metcalf & Chalk,1950, Desch,1957; Kribs, 1959; Miles, 1978). The critical examination of wood anatomy of different species of *Terminalia* Linn. suggests that the wood of *Terminalia tomentosa* W. & A. (BSIP wood slide no. 2293, 360; Pl.1 fig: b.e) shows affinity with the present fossil wood in almost all the anatomical features.

Fossil Records and Comparison

Many fossil woods resembling the genus *Terminalia* Linn. have been reported under the form genus *Terminalioxylon* Schonfeld (1947) mainly from Tertiary sediments of India and abroad (Madel-Angelieva and Muller Stoll,1973, Prakash, 1979, Prasad, 1989, and Guleria 1991). These have been listed in Table along with their differentiating characters. Among them five fossil woods known from Neogene locality of India are showing their close affinity with modern woods of *Terminalia tomentosa* (Ghosh &Roy,1980; Lakhanpal *et al*.,1984; Prakash & Dayal, 1968, Prakash & Tripathi, 1975; Prakash,1966 Ramanujam,1956, Chowdhury & Tandon,1964). It is evident that the fossil woods, *T. tomentosa* have so far been recorded from Tertiary sediments. Suggesting wide spread of the present taxa *Terminalia tomentosa* W. & A. during tertiary period.

3.2 Fungal Infection

Fungi

Class- Ascomycetes

Genus-*Epicoccum* Link 1815

Description

Endophytic fungal spore/conidia are plentifully discovered endogenously in the vessels of the fossil wood. Fine mycelium is additionally seen at spots yet it is broken, poorly preserved and hard to uncover structural points of interest. Hyphae septate, frequently branched, fine 5-6 µm in diameter. Both intercalary and terminal swelling occurs at few focuses. Conidium emerges from the conidiophores. Conidia (spores) are dark colored, with dark pigmentation, almost circular, found as single grain or in cluster, small, 35-45 µm in diameter, mature conidia are multicellular, with roughly thick walls surface.

Comparison

The diagnostic features of the fossil fungus are dark colored spherical conidia (spores) which are multicellular with rough and thick walls. Conidia are globose, mostly 35-40 µm diameter with connecting scar. On comparing with modern analogs, they show close resemblance with Ascomycetes, particularly with genus Epicoccum Link., in which conidia get to be multicellular, darkly pigmented and have rough surface at maturity. It is very common type of endophytic fungus which invades different type of dead or dying plant types. It is present in all geographical regions except polar

region.

***Specimen No.*:** BSIP Museum 40191.

***Type Locality*:** Sharda River section, Tanakpur, Champawat District, Uttarakhand, India.

***Stratigraphic Horizon*:** Holocene (1100±80 years).

Table 1: Fossil Record of the Genus *Terminalia linn*. from *Cenozoic* Period

Fossil Species	Locality	Age	Characters
Terminalioxylon naranjo Schonfeld, 1947	Columbia, South America	Tertiary	Homogeneous rays and non septate fibers
T. porosum Schonfeld, 1947	Columbia, South America	Tertiary	Abundant parenchyma, longer rays and non septate fibers
T. portae Mirioni, 1965	Columbia, South America	Tertiary	Abundant parenchyma, and non septate fibers
T. endengense Boureau, 1955	Sahara, North, Africa	Eocene	Abundant parenchyma, and non septate fibers
T. fezzenense Boureau, 1958	Calancho, North Africa	Eocene	Abundant parenchyma, and non septate fibers
T. erichsenii Musa, 1958	Brazil	Tertiary	Abundant parenchyma, and longer rays
T. welkitii Lemoigne, 1972	Ethiopia	Tertiary	Homogeneous rays
Terminalioxylon sp. Lemoigne, Beauchamp & Samuel, 1974	Ethiopia	Tertiary	Homogeneous rays
T. doubingeri Lemoigne, 1978	Ethiopia	Tertiary	Terminal parenchyma and non septate fibers
T. primigenium Madel-Angeliewa and Mulle- Stoll, 1972	Sudan	Upper Cretaceous or Eocene	Vessel with high frequency and longer rays
T. qeinitzii Madel-Angeliewa and Muller- Stoll, 1973	Sudan	Upper Cretaceous or Eocene	Mostly small vessels in usually multiples, Vasicentric parenchyma
T. intermedium Madel-Angeliewa and Muller- Stoll, 1973	Sudan	Upper Cretaceous or Eocene	Smaller vessels and scanty vasicentric parenchyma
T. edwardsii Madel-Angeliewa and Mulle- Stoll, 1973	Egypt	Oligocene	Abundant parenchyma and longer rays
T. pachitanensis Sukiman, 1977	Java	Miocene	Abundant parenchyma and non septate fibers
T. felixi Ramanujam, 1956	South India	Miocen-Pliocene	Growth ring demarcated by narrow line of parenchyma and small vessels and occasionally septate fibres.
T. burmense Madel-Angeliewa and Muller-Stoll, 1973	Sumatra	Tertiary	Abundant parenchyma and non septate fibres
Terminalioxylon sp. Kramer, 1974	Tertiary	Tertiary	Abundant parenchyma and non septate fibres
T. martrohense Madel-Angeliewa and Muller-Stoll, 1973	Vietnam	Tertiary	Smaller vessel arranged in radial group of 2-7

Table 1 – Cond.,

T. tertiarum (Prakash) Kramer, 1974	Vietnam	Tertiary	Abundant parenchyma and homogeneous rays, terminal parenchyma
T. burmense (Madel-Angeliewa and Muller- Stoll, 1973) Kramer,1974	Vietnam	Tertiary	Abundant parenchyma and non septate fibres
T. coriaceum (Prakash & Awasth) Kramer, 1974	Vietnam	Tertiary	Abundant parenchyma and homogeneous rays
T. densiporosum Kramer, 1974	Indonesia	Tertiary	Vessel with higher frequency, longer rays and terminal parenchyma
T. annanrense Boureau 1950	Indochina	Tertiary	Abundant parenchyma and non septate fibres
T. kratiense Serra,1966	Indochina	Tertiary	Homogeneous rays and non septate fibres
Terminalia tomentosum Choowdhury & Tandon,1964	Burma	Mio-Pliocene	Abundant parenchyma, Homogeneous rays and terminal parenchyma
T. felixi Ramanujam,1956	South India	Tertiary	Terminal parenchyma and non septate fibres
T. speciosum Ramanujam,1956	South India	Tertiary	Abundant parenchyma, non septate fibres
T. sahnii Navale,1956	South India	Tertiary	Homogeneous rays and non septate fibres
T. martandrense Navale,1956	South India	Tertiary	Homogeneous rays
T. grandiporosum Ramanujam, 1966	South India	Tertiary	Terminal parenchyma and non septate fibres
T. indicum (Navale) (Madel-Angeliewa and Muller- Stoll,1973)	Vietnam	Tertiary	Small size vessel and terminal parenchyma
T. varkalensis Awasthi and Ahuja,1982	South India	Tertiary	Scanty parenchyma and non septate fibres
T. chowdhurii Prakash & Navale, 1963	Assam, India	Tertiary	Abundant parenchyma, homogeneous rays and terminal parenchyma
T. tomentosum Prakash,1966	Assam, India	Tertiary	Homogeneous and non septate
T. tertiarum Prakash and Awasthi, 1970	Assam, India	Tertiary	Abundant parenchyma and non septate fibres
T. coriaceum Prakash & Awasthi, 1971	Assam, India	Tertiary	Abundant parenchyma andhomogeneous xylem rays
Terminalioxylon belericum Prakash, Du and Tripathi, 1992	Tipam sandstone, Assam	Middle Miocene	Homogeneous and non septate fibres
T. bikanerense Harsh, Sharma and Suthar,1992	Bikaner, Rajasthan	Tertiary	Abundant parenchyma and non septate fibres
T. felixi Ramanujam, Reddy, 1992	Neyveli, Tamil nadu	Miocene	Terminal parenchyma and non septate fibres

Table 1 – Cond.,

T. palaeocalamansanai Guleria,1991	Rajapadi Gujrat	Eocene	Vessel small to medium, terminal parenchyma abundant, non septate fibres
T. siwalicus Prasad, 1989	Kalagarh, Uttaranchal	Middle - Miocene	Growth ring indistinct, parenchyma scanty
T. varkalensis Awasthi, Ahuja 1982;Agarwal 1998	Neyveli, Tamil Nadu	Miocene	Scanty parenchyma and nonseptate fibres
T. vasicentricum, Harsh, Sharma and Suthar, 1992	Bikaner, Rajasthan	Tertiary	1-2 seriate, homogeneous xylem rays
T. varkalaensis (Awasthi & Ahuja) Shukla, Mehrotra &Guleria, 2013	Habur, Jaisalmer, Rajasthan	Plio-Pleistocene	Xylem rays uniseriate, homo-heterocellular rays and non septate fibres.

DISCUSSIONS AND CONCLUSIONS

Study on the fossil wood collected from the Holocene sediments of Tanakpur area revealed the occurrence of *Terminalia tomentosa* (Roxb). W. & A. (Syn. *Terminalia alata* Heyne ex. Roth, *Terminalia crenulata* Roth and *T. elliptica* Willd. in the Sal (*shorea robusta*) forest of Himalayan foot hills. The comparable taxa, *T. tomentosa* (Roxb.) W. & A. is a large deciduous tree, 20-35 m. high and 1m. diameter. It is an important commercial tree utilized in making different kind of furniture. It is native to southern and South east Asia, India, Nepal, Bangladesh, Myanmar, Thailand, Laos, Cambodia and Vietnam. Most common in prominent part of both dry and moist deciduous forest in southern India.

The genus *Terminalia* has cosmopolitan in palaeodistribution with leaves, fruits, fungal spore and woods reported from all over the world. The earliest record of *Terminalia* (as *Terminaliophyllum*) in the Cretaceous of Bohemia implying that the genus has continued from late Cretaceous to present but was more widely spread during the Tertiary period (Table 1). The occurrence of *Terminalia tomentosa* Roxb. in the Holocene sediments (1100±80yrs) suggest that this taxon might have come in the Himalaya foot hills before it and flourished luxuriantly since then.

The comparable taxa, *Terminalia tomentosa* W. & A. is a large tropical moist deciduous tree found common in the forest of especially in the humid regions of Himalayan foot hills of north- west provinces, Nepal and Sikkim throughout the peninsula suggesting the prevalence of tropical humid climate during Holocene period.

The presence of endophytic fungal spore in the xylem vessels provided good amount of evidence in support of palaeoclimate and palaeoecosystem. This plant–fungus interaction not only provide the data about geological history of major fungal group but also throw the light on the evolution of plant-fungus association and its diversification. The wood decay due to fungal infection is recorded as early as in Upper Devonian and the nature of infection in the fossil woods is almost similar to those found today (Stubblefield et al., 1985; Stubblefield & Taylor, 1988). Since *Epicoccum* is mainly saprophytic in nature, it might have attacked the dead or dying wood of *Terminalia tomentosa*. This fungus is well adopted to grow on a wide range of temperature i.e -5 to 40°C with relative humidity of > 85% and pH 5.0-6.0. It additionally creates a decent amount of pectinase and xylanase responsible for the rot of woody tissues. Because tolerance limit of this fungus, it is cosmopolitan in nature. Hence it is concluded from the above facts that the presence of both *Terminalia tomentosa* as well as fungus *Epicoccum* indicate that a warm and humid tropical climatic condition was prevailing in Tanakpur area during the time of deposition.

The fossil woods cf. *Terminalia manii*, *T. paniculata*, *T. bellerica* reported from the Mio- Pliocene sediments of Himalayan foot hills have also been compared and found that none of these resembles with the present fossil (*Terminalia tomentosa*) growing now a days in the Himalayan foot hills.Thus, it suggested that these *Terminalia* spp. (evergreen taxa) growing during Mio-Pliocene or before it must have extinct from the area due to climatic change and such deciduous taxa (*Terminalia tomentosa* W. & A.) came into existence before at least 1100 ±80 yrs. AD.

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REFERENCES

1. Awasthi, N. & Ahuja, M. (1982). Investigation of some carbonized wood from the Neogene of Varkala in Kerala Coast. Geophytology 12(2): 245-259.
2. Awasthi, N.&Ahuja, M. (1999). Investigation of some carbonized woods from the Neogene of Varkala in Kerala Coast. Geophytology 12: 245-259.
3. Boureau, E. (1950). Contribution a'l' etude palaeoxylologique de l' Indochine, III. *Terminalioxylon annamense* n. sp. Combretaceae des argiles neogenes due sud de l' Annam Central. Bull. Surv. geol. Indochina 29(4): 5-11.
4. Boureau, E. (1955). Etude paleoxylologique du saharre (XXI): Sur un *Terminalioxylon edengense* n. sp., de la pente sud de Edeng, au sud-ouest de l' Adrar Tiguirist (Sahara Sondanais). Bull. Mus. natn. Hist. nat. paris Ser. 27: 247-255.
5. Chowdhury, K. A. & Tandon, K. N (1964). A fossil wood of *Terminalia tomentosa* W. & A. from the Tertiary of Burma. Ann. Bot. N. S. 28: 445-450.
6. Chauhan, M. S, Rajagopalan, G., Philip, G. & Viridi, N. S (2002). Pollen analytical study of late-Holocene sediments from Trans-Yamuna segments of western Doon Valley of Northwest Himalaya. Palaeobotanist 50: 403-410.
7. Desch, H. E (1957). Manual of Malayan Timber Malay. Forest Record 15: 1-328.
8. Duperon, Laudoueneix, M. (1973). Sur un bois fossile de Combretaceae de Tunisie. Anni Mines Geol. Tunis 26: 431-443.
9. Ghosh, P. K & Roy, S. K (1980). Fossil wood of *Terminalia* from the Tertiary of west Bengal. Current Science 49(1): 556-557.
10. Guleria, J. S (1991a). On the occurrence of Carbonised wood resembling *Terminalia* and *Sonneratia* in Palaeogene deposit of Gujarat, Western India Palaeobotanist 39(1): 1-8.
11. Guleria, J. S (1991b). Occurrence of *Duabanaga* and *Terminalia* in Late Tertiary sediments of Bikaner, Rajasthan, Birbal Sahni Centanary Palaeobotanical Conference, Lucknow. 40 (abstract)

12. Harsh, H., Sharma, B. D & Suthar, O. P (1992). Anatomy of petrified woods of Lecythidaceae and Combretaceae from Bikaner (Rajasthan) India. Phytomorphology 42(1-2):87-102.

13. Kribs, D. A. (1959). *Commercial foreign woods on the American market*. Edwards Brothers In: An. Arboz Michigano, Pennsylvania 1-203.

14. Kramer, K. (1974)a. Die Tertiaren holzer sudost Asiens (unter ausschluss der Dipterocarpaceae) 1, Teil. The Tertiary wood of South-East Asia (Dipterocarpaceae excluded) Part-1. Palaeontographica 144B: 45-181

15. Kramer, K. (1974)b. Die Tertiaren holzer sudost Asiens (unter ausschluss der Dipterocarpaceae) 1, Teil. The Tertiary wood of South-East Asia (Dipterocarpaceae excluded) Part-2. Palaeontographica 145B: 1-150.

16. Lakhanpal, R. N. & Guleri, J. S. (1978). A lauraceous leaf impression from the Siwalik beds near Tanakpur, Uttar Pradesh. Geophytology 8: 19-21.

17. Lakhanpal, R. N. & Awasthi, N. (1984). A Late Tertiary florule from near Bhikhnathoree in West Champaran District, Bihar, In *Proc*. Symp. Evolutionary Botany and Biostratigraphy, Calcutta, 1979, eds AK Sharma, GC Mitra, M Banerjee (AK Ghosh Commemoration Volume), *Current Trends in Life Sciences 10 587-596.*

18. Lemoigne, Y. & Beauchamp, J. (1972). Palaeofloras tertiaries de la region de welkite Ethippie, province due shoa. Bull. Soc. geol. Fr. Ser. 7 154: 336-346.

19. Lemoigne, Y., Beauchamp, J.,& Samuel, E. (1974). Etude palaeobotanique des depots volcaniques d' age tertiare des bordures est et oust du system des reifts Ethiopiens. Geobios 7(3): 267-288.

20. Prasad M, Chauhan M. S., Sah M. P. (2002). Morphotaxonomic study on fossil leaves of *Ficus* from Late Holocene sediments of Sirmur District, Himanchal Pradesh, India and their significance in assessment of Past Climate. Phytomorphology 52(1) 45-53.

21. Lemoigne Y (1978). Flores Tertiaries de la haute vallee de I'Omo (Ethiopie). Palaeontographica 165B: 89-157.

22. Metcalfe C. R. & Chalks L (1950). Anatomy of Dicotyledons. 1 & 2. Oxford University Press, Oxford, Pp. 612-620.

23. Madel Angeliewa E & Muller Stoll WR (1973). Kritische studien uber fossile Combretacean holzer: uber holzer vom typus *Terminalioxylon* G. Schonfeld mit einer revision der bischer zu *Evodioxylon* Chiarugi gestellten arren. Palaeontographica 142B: 117-136.

24. Mahajan D. R., Mahabale J. S. (1973). Quaternary flora of Maharashtra. I. Geophytology 2: 175-177.

25. Miles A (1978). Photomicrograph of world woods. Department of Environmental Building Research Establishment London.

26. Navale G. K. B. (1956). *Sapindoxylon indicum* sp. nov. a new fossil wood from the Tertiary beds of South India. Palaeobotanist, 5(2): 73-77.

27. Pearson R. S. & Brown H. P. (1932). Commercial Timbers of India. 1 & 2. Govt. of India, Central Publication Branch, Calcutta.

28. Prakash U. & Navale G. K. B (1963). *Terminalioxylon chowdhurii* sp. nov.- A new fossil dicotyledonous wood

from the Tertiary rocks of Assam. Palaeobotanist 11: 49-53.

29. Prakash U. (1966). Some fossil dicotyledons woods from the Tertiary of eastern India. Palaeobotanist 14: 223-235.
30. Prakash U, & Dayal R. (1968). Fossil woods of *Terminalia* from Kutch. Current Science 37(8): 233.
31. Prakash U. & Tripathi P. P. (1970). Fossil woods from the Tertiary of Hailakandi Assam. Palaeobotanist 18(1): 20-31.
32. Prakash U. & Awasthi N. (1970). Fossil wood from the Tertiary of eastern India. Palaeobotanist 18(1): 32-44.
33. Prakash U. & Awasthi N. (1971). Fossil wood from the Tertiary of eastern India- II. Palaeobotanist, 18(3): 219-225.
34. Prakash U. (1979). Fossil dicotyledonous wood from the Tertiary of Thailand. Palaeobotanist 26(1): 50-62.
35. Prasad M. (1989). Some more fossil woods from the Lower Siwalik sediments of Kalagarh, Uttar Pradesh, India Geophytology 18(2): 135-144.
36. Prasad M. (1994). Morphotaxonomical study on Angiospermous plant remains from the foot-hiils of Kathgodam North India. Phytomorphology 44(1&2): 115-126).
37. Prasad M., Chauhan M. S. & Shah MP (2002). Morphotaxonomic study on fossil leaves of *Ficus* from late Holocene sediments of Sirmur District Himachal Pradesh, India and their significance in assessment of past climate. Phytomorphology 52: 45-53.
38. Prasad M., Agarwal A., Khare E. G. & Sekar B. (2008). Occurrence of the *Anogeissus* Walls in the Holocene 600 yrs. Cal. BP sediments of Himalayan foot Hills, Uttarakhand, India J. ppl. Bioscii 34(2): 181-184.
39. Prasad M., Khare E. G. & Agarwal A. (2008). Existence of *Shorea robusta* (Sal) in the Himalayan foot hills of India since 5600 years BP. Palaeobotanist 57: 497-501.
40. Prasad M., Alok &Kannaujia A. K. (2013). Siwalik (Middle Miocene) flora of Tanakpur area in the Himalayan foot hills of Uttarakhand, India and its palaeoclimatic implications. Palaeontographica (In Press)
41. Ramanujam C. G. K. (1956). On the two new species of *Terminalioxylon* Schonfeld from the Tertiary of south Arcot District Madras. J. Indian bot. Soc. 35(1): 103-113.
42. Ramanujam C. G. K. (1966). A further investigation of the ligneous fossils of Combretaceae from South India. Plaeobotanist 14: 246-255.
43. Rajagopalon G., Mitre V. & Sekar B. (1978). Birbal Sahni Institute Radiocarbon measurement I. Radiocarbon 20(3): 398-404.
44. Schonfeld G. (1947). Holzer aus den Tartiar von Kalumbien. Abh. Senekenb. Naturforsch Gen 475: 1-53.
45. Serra C. (1966). Nouvelle contribution a l'etude paleoxylogique du Combodge, du Laos et du Viet Nam Archs geol. Viet Nam (Saigon) 9: 17-40.
46. Srivastava R., Kapgate D. K. & Chatterjee S (2009). Permineralized fungal remains in the fossil wood of

Barringtonia from the Deccan Intertrappean sediments of Yavatmal District, Maharastra, India. Palaeobotanist 58 :11-19.

47. Srivastava G. P. & Bande M. B. (1992). Fossil wood of *Terminalia* and *Lagerstroemia* from the Late Cenozoic beds of Mahuadanr, Palamau District, Bihar. Palaeobotanist 39(3): 333-337.
48. Shashi, Pandey S. M. & Tripathi P. P. (2006). Fossil leaf impressions from Siwalik sediments of Himalayan foot hills of Uttaranchal, India and their significance. Palaeobotanist 55: 77-87.
49. Shukala A., Mehrotra R. C. & Guleria J. S. (2013). Two dicotyledons woods from the Late Neogene sediments of Jaisalmer, Rajasthan. Palaeobotanist 62(1): 11-17.
50. Sukieman S. (1977). Sur deux boils fossiles du gisement de la region Pachitan a java. Compte Rendus 102 congr. Nat des soc sav Limoges, Sciences fase 1: 197-209.
51. Stubblefield Sara P. & Taylor Thomas N. (1988). Tansley Review No.12-Recent Advances in Palaeomycology. New Phytology 108 :3-25.
52. Stubblefield Sara P., Taylor Thomas N. & Beck Charles B. (1985). Studies of Palaeozoic fungi V. Wood decaying fungi in *Callixylon newbwrryi* from the Upper Devonian. American Journal of Botany 72 :1765-1774.
53. Tiwari R. P. & Mehrotra R. C. (2000). Fossil woods from the Tipam Group of Mizoram, India. Tertiary Research 20(1-4): 85-94.
54. Wheeler E. A., Pearson R. G., La Pasha C. A., Zack T. & Hatley W. (1986). Computer added wood identification: Reference manual North Carolina Agricultural Research Service Bulletin 474: 1-96.
55. Willis J. C. (1973). Dictionary of flowering plant and ferns. Cambridge University Press Cambridge.

APPENDICES

Figures & explanation of figures

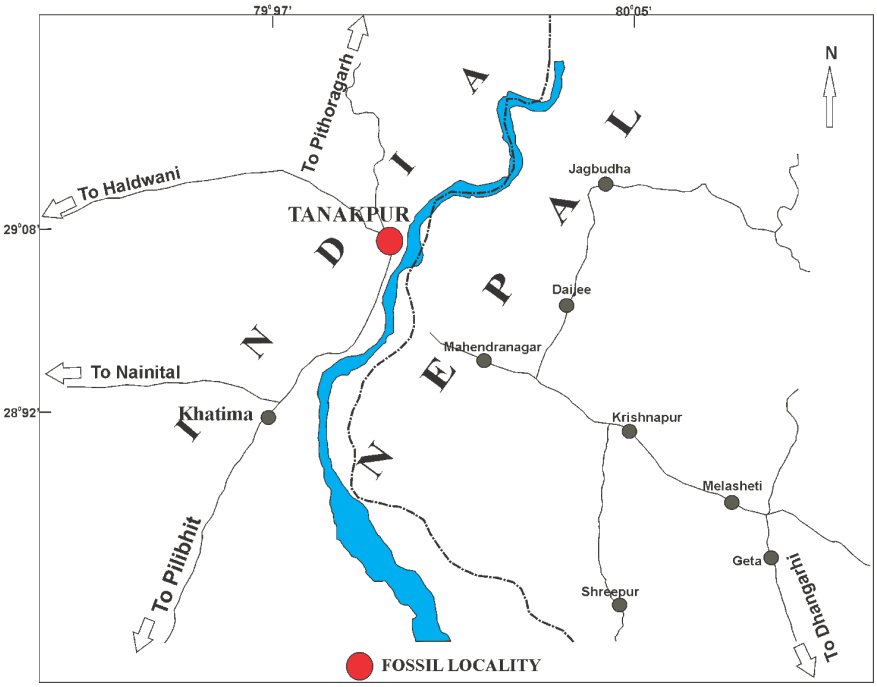

Figure 1: Map Showing Location of Study Site in Tanakpur Area, Uttarakhand, India

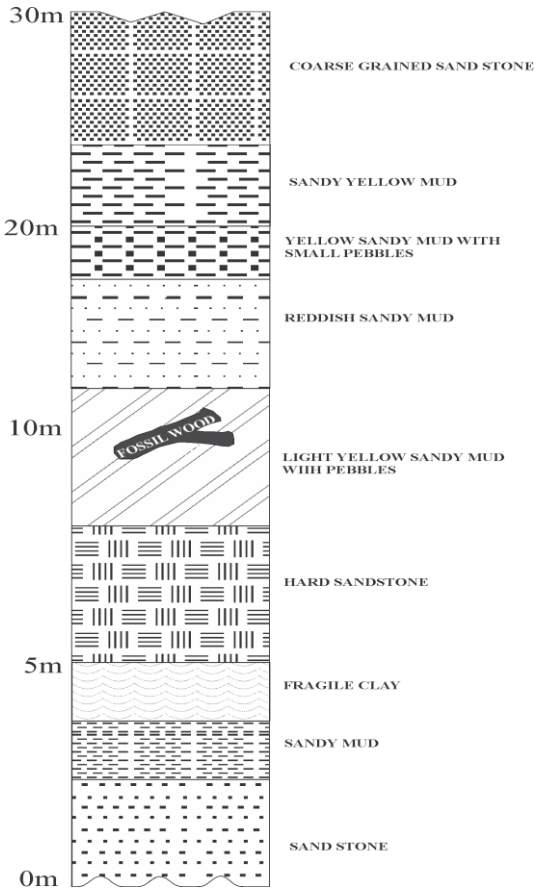

Figure 2: Lithological Column of a Part of Exposed Section (Holocene) Along Sarda River Indicating the Location of Fossil Wood

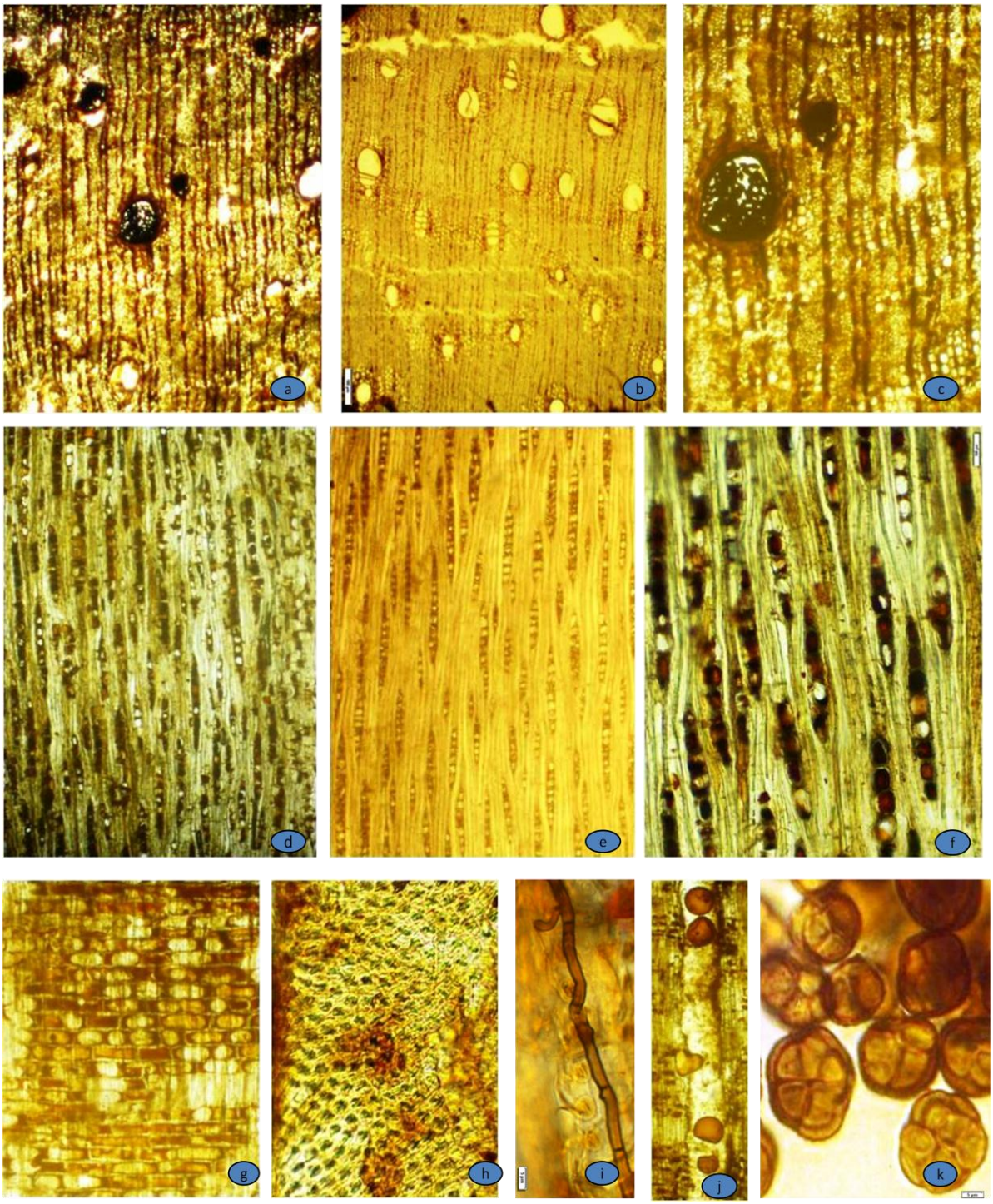

Figure 3

a. Cross section of the fossil woods showing terminal parenchyma and distribution pattern of vessel.
b. Cross section of the modern wood of *Terminalia tomentosa* showing similar anatomical stuctures as found in fossil.
c. Cross section of fossil wood magnified to show detail of paratracheal parenchyma around the vessel and fibres.
d. Tangential longitudinal section of fossil wood showing uniseriate rays with crystalliferous cells.
e. Tangential longitudinal section of modern wood showing similar xylem rays with crystalliferous cells.
f. Tangential longitudinal section of Fossil wood magnified show to detail of xylem rays.
g. Radial longitudinal section of Fossil wood showing homogeneous xylem rays.
h. Intervessel pits.
i. Tangential longitudinal section showing septate fibers.
j. Fossil wood showing presence of fungal spore in the vessel.
k. Magnified view of fungal spore